# SCIENCE AND RELIGION

## I. THE METHODS AND RESULTS OF SCIENCE

JOHN MERLE COULTER, PH.D.
Professor and Head of the Department of Botany,
University of Chicago

A little over twenty years ago, Andrew D. White published a work entitled *History of the Warfare of Science against Theology*. This title suggests the fact that the representatives of science and of religion once occupied hostile camps. Of course we distinguish between *religion* and *theology*, and this distinction is involved in the title of President White's book; but people in general think of theologians as the official representatives of religion; so that to them this so-called conflict meant one between science and religion. This confusion in the popular mind is natural, for the Christian church is the organized representative of the Christian religon, and people know that to become a member of that organization there must often be a profession of belief which sounds to them theological. Moreover, they know that denominations do not differ in religious work, but in theological beliefs, and therefore they conclude that theology is stressed rather than religion, and that any attack on theology involves an attack upon the church, which also stands for religion.

There were sharp conflicts now and then between the representatives of science and of theology, with the usual result that each party was more firmly convinced of its own opinion. This situation has changed completely, and the hostile camps have become allies in a great cause. Religion has discovered that science is honestly searching for the truth, and science has discovered that the Christian religion has a scientific basis. It seems strange to us now that two groups, each searching for the truth in its own way, should have come into conflict. It was certainly unscientific to deny religious truth, just as it was irreligious to deny scientific truth. Truths are not contradictory. If claimed truths are contradictory, then the truth is not clear.

When I say that the situation has changed I do not mean to imply that all the representatives of religion and of science have declared an armistice, for in certain localities and with certain temperaments the old notion of the incompatibility of science and religion persists. But these are merely "hold overs" from a former general situation. The whole tendency today is toward the co-operation of religion and science. In these days to impute to science in general an attitude of opposition to religion is an assumption entirely without foundation. One might as well impute to science hostility to morality, or to patriotism, or to any other noble expression of the human life.

As a necessary introduction to the consideration of the general subject, "The Cooperation of Religion and

Science," there must be some clear understanding of "The Methods and Results of Science." This is necessary not only as a basis for discussion, but also to correct much misapprehension in reference to science, especially on the part of those who are sensitive about its relation to the claims of religion. It is unwise for any scientific man to attempt to speak of all the sciences, but in using one of them as an illustration of methods and results we may be assured that it is representative of all the sciences. It would be of interest, for example, to consider the revelations made in recent years by chemistry and physics as to the constitution and behavior of matter, but I must restrict myself to biology, with its revelations of the world of organisms, to which man belongs. The work in biology most closely related to our purpose is that which deals with evolution and heredity. To consider this work is especially fitting, because the old "warfare" referred to was largely instigated by the claims of organic evolution. The evolution of the material world, called inorganic evolution, aroused wonder, but not apprehension; but when organic evolution came into prominence hostility was aroused, because such evolution seemed to involve man.

The *idea* of organic evolution is as old as our record of men's thoughts, for all the old mythologies are full of it. No modern man, therefore, is responsible for the *idea*, although it is a common misconception to load this responsibility upon certain distinguished students of evolution. Until a little over one hundred years ago, however, organic evolution was a pure speculation, with no basis of scientific work. In other words, it was a philosophy rather than a science. It will be helpful to note briefly, in historical succession, the facts that made some thinking men conclude that evolution might be a *fact*, and not merely a speculation. As a result, they began scientific work, and the study of evolution became a science.

In classifying plants and animals, which was the initial phase of biology, men rigidly defined the different species, the thought being that the different kinds had descended in unbroken succession and unchanged "from the beginning." When more extensive observations were made in the field, numerous intergrades began to be found. The species, as defined, seemed to intergrade freely. In other words, the pigeonhole arrangement, with rigid partitions, did not express the facts. It became evident that species had been defined by man rather than by nature. Some were distinct enough, but many intergraded. It ought to be realized that a species is the conception of man and fluctuates just as do human opinions. Biologists learned, therefore, that the limitations of species are human inventions, and intergrading suggested that one species might come from another, the intergrades marking the trail.

The next observations suggesting that evolution might be a fact had to do with what was called the "power of adaptation." It was observed that plants and animals respond to changes in environment, often in a striking way. I have seen what were regarded as two good species changed into one another by changing from a moist habitat to a dry one, or the reverse. This ability to

change in response to changing conditions seemed to indicate that species are not so rigid and invariable as had been supposed.

As technique developed, and the internal structures of plants and animals became known, it often happened that "rudimentary" structures were found, which never developed to a functioning stage but which occurred fully developed in related forms. For example, it was found that in the developing parrot a full set of embryo teeth begin, but never mature. The inference was natural that these structures had been functional in the ancestors but had been abandoned by some of their descendants. In these days it has become the habit to call these rudimentary structures "vestiges." Plants and animals are full of these vestiges. One well-known illustration in the human body is the vermiform appendix, a functionless vestige in man, but functional in most mammals. It seems safe to say that we are all walking museums of antiquity.

After this succession of facts, there came a revelation which convinced more men that evolution is a fact than any evidence that had preceded. The geologists had begun to uncover that wonderful succession of plants and animals from the earliest geological periods to the present time. They saw in the oldest periods forms unlike any now existing; they saw gradual changes with each succeeding horizon; they saw a steady approach to forms like those of today, until by insensible gradations the present flora and fauna were ushered in.

One illustration may be useful. I happen to be specially interested in the plant group known as gymnosperms (pines, cedars, hemlocks, etc.). This group has the distinction of having the longest continuous record of any group of organisms. This record has now been studied from the coal period to the present time. Moreover, our conclusions as to relationships do not depend upon external resemblance. Modern technique is able to section petrifactions, just as we do living material; so that we know the internal structure as well as the external form. These intimate structures are much more important in indicating relationships than are external resemblances. In this way we have demonstrated the succession of gymnosperm forms from the most ancient geological period to the present time, and the continuity is unbroken between the gymnosperm flora of today and that of millenniums ago. And these two floras differ, not merely in species, but in orders, and the most ancient orders have become extinct.

This geological record, becoming continually more detailed in its interpretation, set men to thinking seriously.

Finally, after all this evidence was in, men began to look around them and realize what they had been doing for centuries in domesticating animals and plants. They had been bringing them from the wild state and changing them so much by the methods of culture that in many cases the wild originals could not be recognized. Most of our cultivated plants, if found in nature associating with their wild originals, would be regarded as extremely distinct species. It was these great changes wrought by cultivating plants and domesticating animals that formed the basis of Darwin's

explanation of the origin of species. He showed how man changed forms by selecting according to his taste or need, and by continuing the selection in the same direction built up a form as different from its wild ancestor as one species is different from another. He simply substituted nature as the agent of selection rather than man, and called his explanation "natural selection." Of course nature could not make a conscious selection, as does man, but Darwin saw nature selecting by means of competition, the best equipped forms surviving, resulting in what Spencer later called "the survival of the fittest."

In the presence of such an array of facts, is it to be wondered at that certain men began the serious, scientific study of evolution?

There is no need to define the various theories advanced to explain the facts. It is important to remember, however, that such men as Lamarck and Darwin were not responsible for the *idea* of evolution, but merely attempted to explain the *fact* of evolution. They were *explainers* rather than *authors*. It is important also to realize the method they used. It may be called the method of comparison and inference. Plant and animal forms were observed, and resemblances were assumed to indicate relationship through descent. It was not demonstration, but inference based on observation. Darwin carried the method to the limit of its possibilities, observing not a small range of forms, but observing through several years a world-wide range of forms, in connection with the famous voyage of the Beagle. His caution is also indicated by the fact that his observations were under consideration for some twenty years before his conclusions were published. His facts were so undoubted, and his case so well put, that his explanation of evolution attracted immediate attention and really fought the battle of evolution. This is what made his explanation an epoch in the history of biological science.

As facts multiplied, the current explanations were found to be inadequate to explain all of them. This led to a general misconception of the situation by the uninformed public. For example, more intensive study developed the fact that Darwin's explanation did not always explain. His name is so identified with evolution in public thought that this criticism of the universal application of his conclusions by certain scientific men was taken to mean that the theory of evolution was being abandoned. The real situation is that every proposed *explanation* may prove inadequate, and yet the *fact* of evolution remains to be explained. All the explanations offered are partial explanations, which simply means that no one of them applies to all the facts. We need them all and more besides. So far from being abandoned, evolution is the basis of all biological work today.

The method of comparison and inference continued until the beginning of the present century. Then came a new epoch in the history of evolution. This was ushered in by the work of DeVries, who introduced the *experimental* study of evolution. The problem was to discover whether one species actually produces another one. It had been inferred that it does, but inference is not demonstration. By means of care-

fully controlled pedigree cultures De Vries discovered a plant in the actual performance of producing occasionally a new form among its numerous progeny. This form bred true and preserved its distinctive characters; in other words, it was a new species. Many such species have now been observed originating in this way, both in plants and animals. That one species can produce another one is no longer inferred, but demonstrated, and demonstrated repeatedly. There is no longer any doubt, therefore, that evolution is a fact; it is quite a different question whether the proposed explanations are adequate. For our purpose, this means that our conceptions of religion must include this fact. Science is discovering methods of operation, known as laws. The relation of religion to this situation is to develop conceptions as to the origin of these laws. The two fields are not contradictory but supplementary.

This outline of methods and results in one phase of one science is illustrative of all scientific investigation. It is uncovering facts by experimental demonstration and is taking less account of inferences. In the field of evolution, when inferences were the only results, it was natural to extend inference to the evolution of the plant and animal kingdoms, and this involved the origin of man. In these days there is no such attempt, for experimental demonstration of the evolution of the whole series of organic forms, culminating in man, is clearly impossible. Biologists, therefore, are no longer interested in the whole story of evolution but only in discovering experimentally how one species may produce another one. The *fact* of evolution is established, but the whole story of evolution must remain an inference.

There is another result of scientific investigation which should be realized and understood. It may be called the development of the scientific spirit. Our schemes of education are developing it more and more, and your constituencies will include more of it than did those of your predecessors. The scientific spirit means a certain attitude of mind, which may be described best by speaking of some of its characteristics.

1. *It is a spirit of inquiry.*—In our experience we encounter a vast body of established belief in reference to all important subjects, such as society, government, education, religion, etc. It is well if our encounter be only objective, for it is generally true, and a more dangerous fact, that we find *ourselves* cherishing a large body of belief, often called hereditary, but really the result of early association. Nothing seems more evident than that all this established belief which we encounter belongs to two categories: (1) the priceless result of generations of experience, and (2) heirloom rubbish. Unfortunately, the discovery of the latter has often resulted in weakening the hold of the former. The young inquirer, or the non-logical inquirer, is in danger of condemning all the conclusions of the past when one is found wanting.

Toward this whole body of established belief the scientific attitude of mind is one of unprejudiced inquiry. It is not the spirit of iconoclasm, as some would believe; but an examination of the foundations of belief. The

spirit which resents inquiry into any belief, however cherished, is the narrow spirit of dogmatism and is as far removed from the true scientific attitude as the shallow-minded rejection of all established beliefs. The childhood of the race accumulated much which its manhood is compelled to lay aside, and the world needs a thorough going-over of its stock in trade. Such work cannot be done all at once, or once for all, for it must be a gradual sloughing off as the spirit of inquiry becomes more generally diffused.

It must be evident that this spirit is diametrically opposed to intolerance, and that it can find no common ground with those who confidently affirm that the present organization of society is as good as it can be; that the present republics of the world represent the highest possible expression of man in reference to government; that the past has discovered all that is best in education; that the mission of religion is to conserve the past rather than to grow into the future. This is not the spirit of unrest, of discomfort, but the evidence of a mind whose every avenue is open to the approach of truth from every direction. Like the tree, it is rooted and grounded in all the eternal truths that the past has revealed, but is stretching out its branches and ever-renewed foliage to the air and sunshine, and taking into its life the forces of today.

In his essay on Intellect, Emerson says:

> God offers to every mind its choice between truth and repose. Take which you please, you can never have both. Between these as a pendulum, man oscillates. He in whom the love of repose predominates will accept the first creed, the first philosophy, the first political party he meets, most likely his father's. He gets rest, commodity, and reputation; but he shuts the door of truth. He in whom the love of truth predominates will keep himself aloof from all moorings, and afloat. He will abstain from dogmatism, and recognize all the opposite negations between which, as walls, his being is swung. He submits to the inconvenience of suspense and imperfect opinion, but he is a candidate for truth, as the other is not, and respects the highest law of his being.

Dogmatism still finds many victims, for education has not yet touched the majority; but every day the possible victims are becoming fewer in number, and those who seek to lead opinion must presently abandon the method of bare assertion. The factors in this general intellectual progress are perhaps too subtle and interwoven to analyze with certainty, but conspicuous among them is certainly the development of scientific training. For fear of being misunderstood, I hasten to say that this beneficent result of scientific training does not come to all those who cultivate it, any more than is the Christ-like character developed in all those who profess Christianity. I regret to say that even some who bear great names in science have been as dogmatic as the most rampant theologian. But the dogmatic scientist and theologian are not to be taken as examples of "the peaceable fruits of righteousness," for the general ameliorating influence of religion and of science is none the less apparent.

2. *The scientific spirit demands a real connection between an effect and its claimed cause.*—It is in the laboratory

that one first really appreciates how many factors must be taken into the count in considering any result and what an element of uncertainty an unknown factor introduces. In the very simplest cases, where we have approximated certainty in the manipulation of factors to produce results, there is still lurking an element of chance, which simply means an unknown and hence uncontrolled factor. Even when the factors are well in hand, and we can combine them with reasonable certainty that the result will appear, we may be entirely wrong in our conclusion as to what in the combination has produced the result.

For example, we have been changing the forms of certain plants at will by supplying in their nutrition varying combinations of certain substances. By manipulating the proportions of these substances we produce the expected result. It was perhaps natural to conclude that the chemical nature of these particular substances produce the result, and our prescription was narrowed down to certain substances. Now, however, it is discovered that the results are not due to the chemical nature of these substances, but to a particular physical condition which is developed by their combination, a condition which may be developed by the combination of other substances as well; so that our prescription is much enlarged. In this operation we are thus freed from slavery to particular substances, and must look only to the development of a particular physical condition.

It seems to me that there is a broad application here. In education, we are in danger of slavery to subjects. Having observed that certain ones may be used to produce certain results, we prescribe them as essential to the process, without taking into account the possibility that other subjects may produce similar results.

In religion, we are in danger of formulating some specific ritual as essential to the result, and of condemning those who do not adhere to it. This is the essence of formalism, and its logical outcome, unchecked by common sense, is illustrated by the final expression of Jewish temple worship. That there may be many lines of approach to a given result, if that result be a general condition, is a hard lesson for mankind to learn.

If it is so difficult to get at the real factors of a simple result in the laboratory, and still more difficult to interpret the significance of factors when found, in what condition must we be in reference to the immensely more difficult and subtle problems which confront us in social organization, government, education, and religion; especially when it is added that the vast majority of those who have offered answers to these problems have had no conception of the difficulties involved in reaching absolute truth. It is evident that in the vast problems which concern human welfare in general, we are but groping our way, and that our answers as yet are largely empirical. The proper effect of such knowledge is not despair but a receptive mind. In my judgment, therefore, the diffusion of the scientific spirit will make it more and more difficult for anyone with a nostrum to get a hearing.

The prevailing belief among the untrained is that any result may be

explained by some single factor operating as a cause. They seem to have no conception of the fact that the cause of every result is made up of a combination of interacting factors, often in numbers and combinations that are absolutely bewildering to contemplate. An enthusiast discovers some one thing which he regards, and which perhaps all unprejudiced and right-thinking people regard, as an evil in society or in government, and straightway this explains for him the whole of our present unhappy condition. This particular tare must be rooted up, and rooted up immediately, without any thought as to the possible destruction of the plants we must cultivate. The abnormal tissue must be destroyed without reference to the fact that the method of destruction may debilitate the normal tissue.

This habit of considering only one factor, when perhaps scores are involved, indicates a very primitive and untrained condition of mind. In the youth of science it often threw its votaries into hostile camps, each proclaiming rival factors, when the problem really demanded all the factors they had and many more besides.

It is fortunate when the leaders of public sentiment have gotten hold of one real factor. They may overdo it and work damage by insisting upon some special form of action on account of it, but so far as it goes it is the truth. It is more apt to be the case, however, that the factor claimed holds no relation whatever to the result. This is where political demagoguery gets in its most unrighteous work and preys upon the gullibility of the untrained, and is the soil in which the noxious weeds of destructive socialism, charlatanism, and religious cant flourish.

It is to such blindness that scientific training is bringing a little glimmer of light, and when the world one day really opens its eyes, and it is well if it open them gradually, the old things will have passed away.

3. *The scientific spirit keeps one close to the facts.*—One of the hardest things in my teaching experience has been to check the tendency of many students to use one fact as a starting-point for a flight of fancy that is simply prodigious. Such a tendency is corrected, of course, when facts accumulate somewhat, and flight in one direction is checked by a pull in some other direction; but most of us have this tendency, and the majority are so unhampered by facts that flight is free. This exercise is beautiful and invigorating if it is recognized to be what it really is, a flight of fancy; but if it results in a system of belief it is a deception.

There seems to be abroad a notion that one may start with a single, well-attested fact, and by some logical machinery construct an elaborate system and reach an authentic conclusion; much as the world has imagined for more than a century that Cuvier could do if a single bone were furnished him. The result is bad, even though the fact have an unclouded title; but it too often happens that great superstructures have been reared on a fact which is claimed rather than demonstrated.

We are not called upon to construct a theory of the universe upon every well-attested fact, and the sooner this is learned the more time will be saved and the more functional will the observ-

ing powers remain. Facts are like stepping-stones; so long as one can get a reasonably close series of them he can make progress in a given direction; but when he steps beyond them he flounders. As one travels away from a fact, its significance in any conclusion becomes more and more attenuated, until presently the vanishing-point is reached, like the rays of light from a candle. A fact is really influential only in its own immediate vicinity; but the whole structure of many a system lies in the region beyond the vanishing-point.

Such "vain imaginings" are delightfully seductive to many people, whose life and conduct are even shaped by them. I have been amazed at the large development of this phase of emotional insanity, commonly masquerading under the name of "subtle thinking." Perhaps the name is expressive enough, if it means thinking without any material for thought. One of the great dangers of our educational system is in laying special stress on training. There is danger of setting to work a mental machine without giving it suitable material upon which it may operate, and it reacts upon itself, resulting in a sort of mental chaos. An active mind turned in upon itself, without any valuable objective material, can never reach any very valuable results.

It may not be that science is the only agency, apart from common sense, which is correcting this tendency; but it certainly teaches most impressively, by object-lessons which are concrete and hence easiest to grasp, that it is dangerous to stray away very far from the facts, and that the farther one strays away the more dangerous it becomes and almost inevitably leads to self-deception.

To summarize, it may be said that the attitude of mind represented by the scientific spirit must bring independence in observation and conclusion, some idea as to what an exact statement is and some conception of what constitutes proof.

The great contributions of science we must reckon with in our field of religion, therefore, are knowledge of the facts of nature and an attitude of mind toward facts in general.

Any field, whether religion or science, is to be estimated by its ideals, even though its occasional performance may be open to criticism. You are familiar with the ideals of religion. I wish to summarize for you the ideals of science. They are (1) to understand nature, that the boundaries of human knowledge may be extended, and man may live in an ever-widening perspective; (2) to apply this knowledge to the service of man, that his life may be fuller of opportunity; and (3) to use the method of science in training man, that he may solve his problems and not be their victim.